COMPARATIVE STUDY OF THE STRAIN SIGNAL AND THE EDITED STRAIN SIGNAL

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Report submitted in fulfilment of
The requirements for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

ABSTRACT

This study presents the comparative study between the original strain signal and its edited strain signal. In this study, the data of fatigue strain loading on an automobile coil spring was used and the purpose to this component is because it been identified as one of the critical component in an automobile. The strain signal editing process was performed by removing low amplitude cycles were eliminated based on the cut-off level of the signal energy distribution in the time representation. Thus, the new edited signal was obtained which has retained almost 100% of the original fatigue damage and has equivalent signal statistic. The original and edited strain signals were analysed for predicting the fatigue damage of the coil spring. A comparison study of the fatigue damage and the highest damage zone obtained from the original strain signal and the edited strain signal carried out. From the result obtained, the prediction of the fatigue damage and the highest damage zone for both strain signals original and edited is equivalents. Hence, for the laboratory fatigue testing the shortened signals that was produced from damage editing process can be used as a tool to accelerate the fatigue testing.

ABSTRAK

Kajian ini membentangkan kajian perbandingan di antara isyarat terikan yang asal dan isyarat terikan yang telah disunting. Dalam kajian ini, data beban terikan lesu pada pegas gegelung kereta telah digunakan dan ini adalah kerana komponen ini telah dikenal pasti sebagai salah satu komponen penting dalam automobil. Proses penyuntingan isyarat terikan dilakukan dengan mengeluarkan kitaran amplitude rendah telah dihapuskan berdasarkan peringkat potong taburan tenaga isyarat dalam perwakilan masa. Oleh itu, isyarat baru yang telah disunting diperolehi mengekalkan hampir 100% kerosakan lesu yang asal dan mempunyai statisti isyarat yang setara. Isyarat terikan asal dan yang telah disunting itu dianalisa untuk meramalkan kerosakan lesu lingkaran spring. Satu kajian perbandingan kerosakan lesu dan zon kerosakan tertinggi yang diperoleh daripada isyarat terikan asal dan isyarat terikan disunting dijalankan. Berdasarkan keputusan yang diperolehi, ramalan kerosakan lesu dan zon kerosakan tertinggi bagi kedua-dua isyarat terikan asaldan isyarat terikan yang telah disunting adalah setara.Oleh itu, untuk kajian makmal, isyarat yang dipendekkan yang terhasil daripada proses penyuntingan kerosakan boleh digunakan sebagai alat untuk mempercepatkan ujian lesu.

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LIST OF SYMBOLS

ε_e	Elastic Component Cyclic Strain
σ_a	Cyclic Stress Amplitude
σ_f'	Fatigue Strength Coefficient
N_f	Number Cycle Failure
b	Fatigue Strength Coefficient
ε_p	Plastic Component Cyclic Strain Amplitude
ε_f'	Fatigue Ductility Coefficient
c	Fatigue Ductility Coefficient
$2N_t$	Transition Life
E	Elongation
σ_0	Mean Stress
σ_{max}	Maximum Stress
D	Damage
X	Damage Criterion
N_i	Fatigue Life At Constant Stress Level S_i
n_i	Number Applied Load Cycles At Constant Stress LevelS_i
S_1	Stress 1
S_2	Stress 2
r	Radius
K	Stiffness
w	Translating Window
τ	Time
t	Time
f	Frequency
exp	Exponent
∞	Infinity
π	22/7

LIST OF ABBREVIATIONS

STFT	Short Time Fourier Transform
SAE	Society Of Automotive Engineer
ASTM	American Society For Testing And Material
LEFM	Linear Elastic Fracture Mechanics
NDT	Non-Destructive Testing
FFT	Fast Fourier Transform
3D	3-Dimensional
FEM	Finite Element Method
FEA	Finite Element Analysis
CAD	Computer Aided Design
S-N	Stress Life
E-N	Strain Life

CHAPTER 1

INTRODUCTION

1.1 Introduction

Suspension is the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. This is important for absorbing bumps in rough terrain, gracefully landing jumps, and getting the right amount of body lean and weight transfer in turns. Both end of this component are fixed to the wheel and the chassis. Suspension components, along with wheel rims and brake components are un-sprung masses, which make weight reduction important for ride quality and response as well as for reducing the total vehicle weight. Each of the automotive suspension system has two goals, that is passenger comfort and vehicle control. Comfort is provided by isolating the passengers vehicle's from road disturbances like bumps or potholes. Control is achieved by keeping the car body from rolling and pitching excessively, and maintaining good contact between the tire and the road.

The most of the failure observed in the real structure and mechanical component are due to the fatigue. Fatigue can be analysed using either three method that is Stress-Life (*S-N*), Strain-Life (*ε-N*) and Crack-Growth Method. In the design of the real system subjected to the environment loadings, both the fatigue strength and dynamic properties of the external loads are important.

Chromium steels are a family of special grade of iron-based alloys that contain at least 10% of chromium in their composition of steels. Chromium steels have remarkable resistance to corrosion. Due to its characteristic chromium steel is use to make the suspension spring coil that can withstand corrosion and able to withstand large load applied to the coil.

1.2 Project Background

This is project about comparative study of strain signal and edited strain signal. This project will use a few method that need to be taken into consideration to successfully accomplish this project. The methods that are going to use is strain-life method. There are three models in strain life method that is coffin Manson, Morrow and Smith Watson Topper. Fatigue is the most important failure mode to be considered in a mechanical design. Under the action of oscillatory tensile stresses of sufficient magnitude, a small crack will initiate at a point of the stress concentration. Once the crack is initiated, it will tend to grow in a direction orthogonal to the direction of the oscillatory tensile loads.

Fatigue analysis is an analysis to determine fatigue failure of a certain products or certain material. Usually fatigue analysis is done using fatigue software. In fatigue analysis nCode software packages is usually used to run the analysis. There are two kind of software, which is GlyphWorks® software packages and also design life software packages. This two software provide different display of result of fatigue analysis. For this project fatigue damage editing was done using GlyphWorks® software packages, and for the determining the value of fatigue damage using design life software packages. Validation process is used in this project to verify whether the result of fatigue damage of original strain signal and edited strain signal is the same or not. Theoretically, the result of the fatigue damage of original and edited strain signal should be the same.

1.3 Problem Statement

The current strain signal consist noise that did not contribute to the fatigue damage value. In order to remove the noise Short Time Fourier Transform (STFT) method is use to remove low cycle amplitude from strain signal, based on gate value. Gate value is minimum amplitude of the strain signal that will contribute to the fatigue damage. After the damage editing process the length of strain signal in second is shorten to a certain value. So, this process is used to accelerate the fatigue analysis. By using the original strain signal, the fatigue analysis takes longer time to finish compared to edited strain signal.

1.4 Objectives

The Objective of the project is:

1) Comparative study between the original strain signal and edited strain signal should give the same value of the fatigue damage. To show that the noise that been removed did not contribute to the fatigue damage value.

2) Comparison study of fatigue damage for different road profile using strain life approach. Different road profile shows that different stress applied to the suspension spring coil which is highway road, university road and public road.

1.5 Hypothesis

The value of fatigue damage for original and edited strain signal should be the same after damage editing process of the strain signal. The signal that been removed did not contribute to the fatigue damage value. after damage editing process of the original strain signal, the signal shorten and when running the analysis the edited signal will finish analysis much faster compared to the original strain signal.

Different road profile show different damage value. the public road should show the highest damage value followed by university road and highway road show the lowest damage value due to its surface of road that are smooth well-made compared to the public road.

1.6 Scope of Research

The first element that needs to be considered that is to perform finite element analysis using Patran Nastran MSC fatigue software. MSC Fatigue is a Finite element based durability and damage tolerance solver that enables users to perform comprehensive durability analysis. Finite element analysis programs can tell you where stress “hot spots” exist, but on their own can’t tell you whether those hot spots are critical areas for fatigue failure, or when fatigue might become a problem. MSC Fatigue enables the engineers to quickly predict how long products will last under certain loading conditions.

The second element is to perform fatigue damage analysis using nCode DesignLife® Software packages. By importing the result of static loading from the MSC fatigue, it will be used to run analysis in DesignLife® Software. The result will be show in a form of finite element display. It also shows the result of fatigue damage with colour contour for the finite element display.

The third element is to run the fatigue damage editing process. This process will be running using software nCode GlyphWorks® software packages. nCode GlyphWorks® is a powerful data processing system for engineering test data analysis with specific application for fatigue analysis. Users can simply create an analysis workflow by ‘drag and dropping’ analysis building blocks. In addition to general signal processing, GlyphWorks® provides leading fatigue analysis capabilities for measured data. The signal noise will be removed from the original strain signal.

The last element is validation process. This process will show the comparison between fatigue damage values of original with edited strain signal. At the end of the project we will see which road profile will give the highest and lowest fatigue damage value.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews about literature review of some recent project or existing experiment. In this project, this chapter will reviews about the fatigue, methods in fatigue prediction, comparison of methods in fatigue and last but not least is strain signal damage editing.

2.2 Fatigue

Fatigue is the process of progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains at some point or points and that may culminate in cracks or complete fracture after a sufficient number of fluctuations. If the maximum stress in the specimen does not exceed the elastic limit of the material, the specimen returns to its initial condition when the load is removed. A given loading may be repeated many times, provided that the stresses remain in the elastic range. Such a conclusion is correct for loadings repeated even a few hundred times. However, it is not correct when loadings are repeated thousands or millions of times. In such cases, crack will occur at a stress much lower than static breaking strength. This phenomenon is known as fatigue. (Ariduru 2004)

To be effective in averting failure, the designer should have a good working knowledge of analytical and empirical techniques of predicting failure so that during the prescribed design, failure may be prevented. That is why in the failure analysis prevention is of critical importance to the designer to achieve a success.

2.3 Stress-Life Based Approach (*S-N* Method)

For the fatigue design and components, several methods are available. All require similar types of information. These are the identification of candidate locations for fatigue failure, the load spectrum for the structure or component, the stresses or strains at the candidate locations resulting from the loads, the temperature, the corrosive environment, the material behaviour, and a methodology that combines all these effects to give a life prediction. Prediction procedures are provided for estimating life using stress life (Stress vs. Number of cycle's curves), hot-spot stresses, strain life, and fracture mechanics. With the exception of hot-spot stress method, Figure 2.1 shows all these procedures have been used for the design of aluminium structures (Rise et al. 1988).

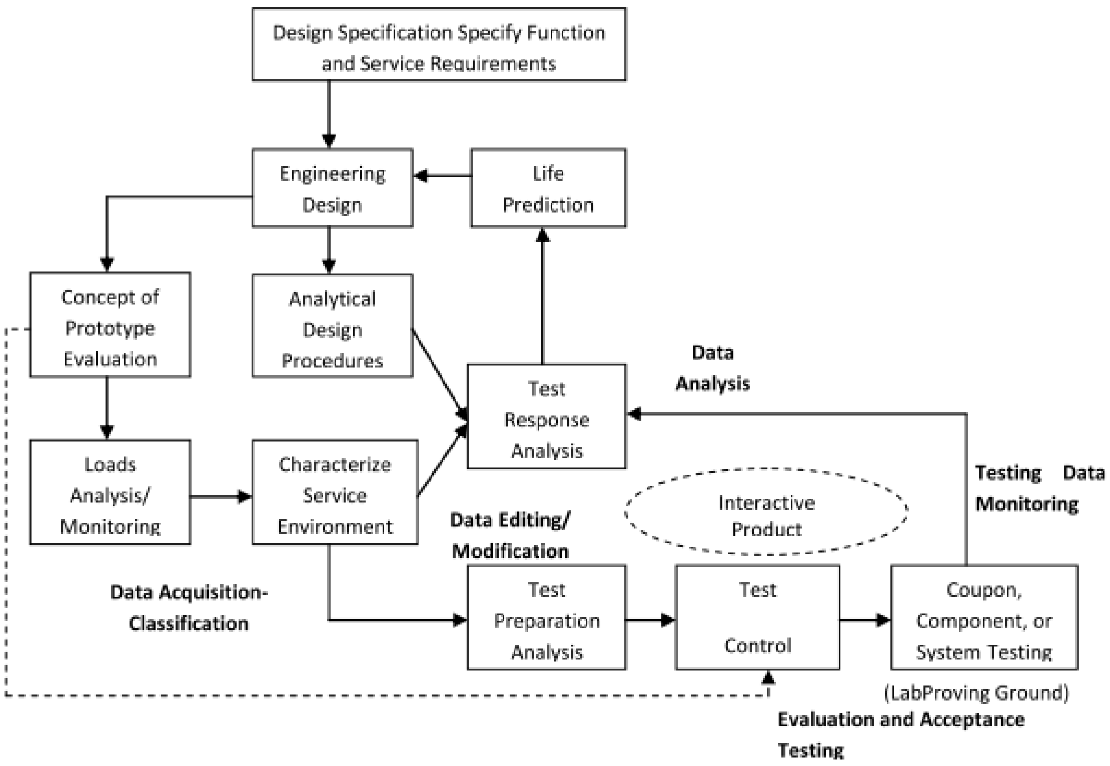

Figure 2.1: Functional diagram of engineering design and analysis

Sources: Rise et al. (1988)

Since the well-known work of Wohler in Germany starting in the 1850's, engineers have employed curves of stress versus cycles to fatigue failure, which are often called *S-N* curves (stress-number of cycles) or Wohler's curve (Lalanne et al.1999). Since the well-known work of Wohler in Germany starting in the 1850's, engineers have employed curves of stress versus cycles to fatigue failure, which are often called *S-N* curves (stress-number of cycles) or Wohler's curve.

The basis of the stress-life method is the Wohler *S-N* curve, that is a plot of alternating stress, *S*, versus cycles to failure, *N*. The data which results from these tests can be plotted on a curve of stress versus number of cycles to failure. This curve shows the scatter of the data taken for this simplest of fatigue tests. A typical *S-N* material data can be seen in Figure 2.2. The arrows imply that the specimen had not failed in 10^7 cycles (Lalanne et al. 1999).

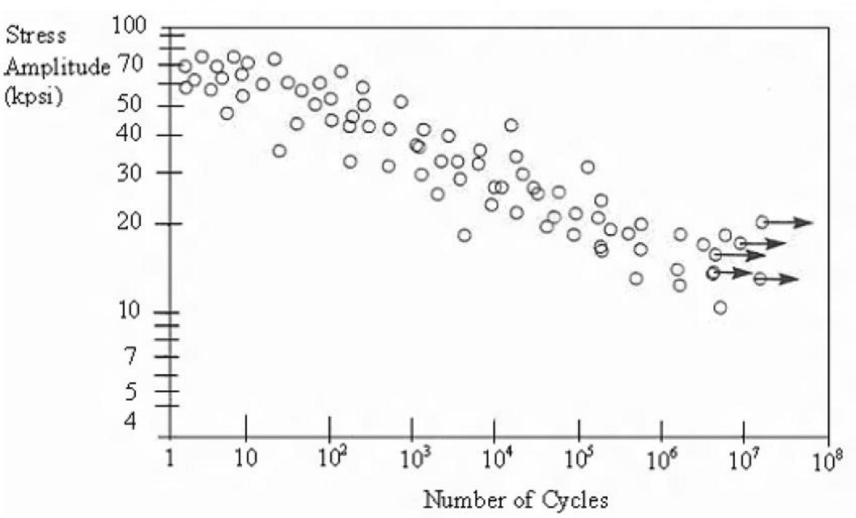

Figure 2.2: A typical *S-N* material data

Sources: Ariduru (2004)

2.4 Strain-Life Based Approach (ε-N Method)

The Strain-Life method is based on the observation that in many components the response of the material in critical locations such as notches is strain or deformation dependent. In the Strain-Life approach the plastic strain or deformation is directly measured and quantified. The Stress-Life approach does not account for plastic strain. (J. A. Bannantine 1990)

Although most engineering structures and components are designed such that the nominal loads remain elastic, stress concentrations often cause plastic strains to develop in the vicinity of notches. Due to the constraint imposed by the elastically-stressed material surrounding the plastic zone, deformation at the notch root is considered strain-controlled.

Crack growth is not explicitly accounted for in the Strain-Life method. Because of this, Strain-Life methods are often considered crack initiation life estimates. For some applications, the existence of a crack is an overly conservative criterion for failure. In these situations, fracture mechanics methods may be employed to determine crack propagation life from an assumed initial crack size to a final crack length. Total lives are then reported as the sum of the initiation and propagation segments.

The local Strain-Life approach has gained acceptance as a useful method of evaluating the fatigue life of a notched component. Both the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE) have recommended procedures and practices for conducting strain-controlled tests and using these data to predict fatigue lives. (J. A. Bannantine 1990)

2.4.1 Strain-Life Behaviour

In 1910, Basquin observed that Stress-Life data could be modelled using a power relationship, which results in a straight line on a log-log plot. This observation corresponds to elastic material behaviour in the Strain-Life approach. The Basquin equation can be expressed in terms of true elastic strain amplitude as:

$$\varepsilon_e = \frac{\sigma_a}{E} = \frac{\sigma_f'}{E}\left(2N_f\right)^b \tag{2.1}$$

Where: ε_e is the elastic component of the cyclic strain amplitude

σ_a is the cyclic stress amplitude

$\sigma' f$ is the regression intercept called the fatigue strength coefficient

N_f is the number of cycles to failure

b is the regression slope called the fatigue strength exponent

In the 1950's Coffin and Manson independently found that plastic Strain-Life data could also be modelled using a power relationship:

$$\varepsilon_p = \varepsilon_f^{'}\left(2N_f\right)^c \tag{2.2}$$

Where: ε_p is the plastic component of the cyclic strain amplitude

$\varepsilon_f^{'}$ is the regression intercept called the fatigue ductility coefficient

N_f is the number of cycles to failure

c is the regression slope called the fatigue ductility exponent

The Strain-Life Curve can be formed by summing the elastic and plastic components:

$$\varepsilon_t = \varepsilon_e + \varepsilon_p \tag{2.3}$$

$$\varepsilon_t = \frac{\sigma_f^{'}}{E}\left(2N_f\right)^b + \varepsilon_f^{'}\left(2N_f\right)^c \tag{2.4}$$

The influence of the elastic and plastic components on the strain-life curve is shown in Figure 2.3.

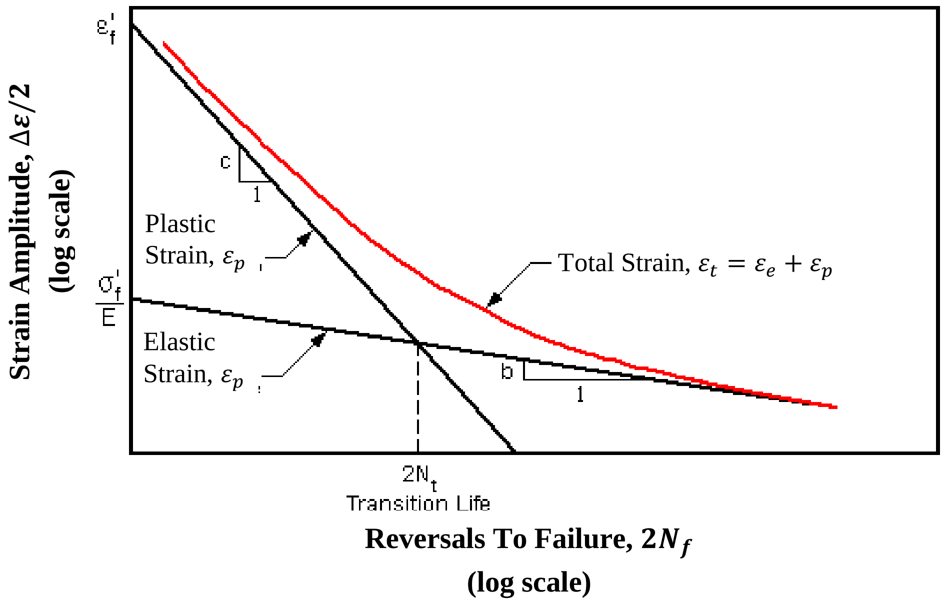

Figure 2.3: Typical strain-life curve

Sources: J. A. Bannantine (1990)

The transition life $2N_t$ represents the life at which the elastic and plastic strain ranges are equivalent. It can be expressed by the following:

$$2N_t = \left(\frac{\varepsilon_f' E}{\sigma_f'}\right)^{\frac{1}{b-c}} \tag{2.5}$$

As shown in Figure 2.3, elastic strains have a greater influence on fatigue lives above the transition life. Plastic strains have a greater influence below the transition life. Thus the transition life provides a convenient delineation between low-cycle and high-cycle fatigue regimes.

Note that at long fatigue lives the fatigue strength $\left(\frac{\sigma_{f'}}{E}\right)$ controls the fatigue performance and the Strain-Life and Stress-Life approaches give essentially the same results. For short fatigue lives, plastic strain is dominant and fatigue ductility $(\sigma_{f'})$ controls the fatigue performance. The optimum material is therefore one that has